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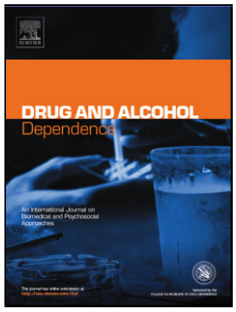

Significant decrease in the rate of fatal alcohol poisonings in Finland validated by blood alcohol concentration statistics

Pirkko Kriikku, Ilkka Ojanperä

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Significant decrease in the rate of fatal alcohol poisonings in Finland validated by blood alcohol concentration statistics

Pirkko Kriikku[a,b], Ilkka Ojanperä[b,a],

a. Forensic Toxicology Unit, National Institute for Health and Welfare, P.O.Box 30, 00271 Helsinki, Finland
b. Department of Forensic Medicine, University of Helsinki, P.O.Box 40, 00014 Helsinki, Finland

Corresponding author: Pirkko Kriikku (pirkko.kriikku@thl.fi)

Highlights

- 32-year prevalence of fatal alcohol poisonings in Finland was investigated
- high medico-legal autopsy rate enabled consistent accumulation of data
- post-mortem toxicology rate ranged between 8.1% and 14.0%
- median fatal blood alcohol level was 3.2 g/kg showing a slightly decreasing trend
- significant decrease in alcohol poisoning mortality was found valid

Abstract

Background Alcohol may cause death directly by acute poisoning, as well as induce illnesses or accidents that lead to death. Our research question was whether the current decreasing trend in acute fatal alcohol poisonings in Finland is a real phenomenon or an artefact caused by possible changes in the process of determining the cause of death.

Methods All cases in the national post-mortem toxicology database in which the underlying cause of death was acute alcohol poisoning in 1987–2018 were investigated in terms of blood alcohol

concentration (BAC), age and gender. The number of acute alcohol poisonings was compared to the number of deaths from alcohol induced illness in the post-mortem toxicology database.

Results A total of 12 126 acute alcohol poisoning cases were retrieved. Between 2004 and 2017 the number of acute alcohol poisonings decreased 60.1%. At the same time the number of alcohol induced illnesses in the study material remained stable or decreased marginally.

The median BAC in all acute alcohol poisonings was 3.2 g/kg. The annual median BAC values showed a small but significant decrease over the study period. The proportion of women in acute alcohol poisonings increased significantly over the study period, from 17.1% to 22.3%. Women were on average 2.5 years older than men.

Conclusions On grounds of the BAC statistics and supporting evidence, we conclude that the significant decrease in the number of fatal alcohol poisonings is true and likely reflects changes in the overall consumption of alcohol.

Keywords: Alcohol, acute fatal alcohol poisoning, mortality, medico-legal autopsy, blood alcohol concentration

1. Introduction

Alcohol is a major cause of mortality and morbidity in Finland and worldwide (Ramstedt 2002, Westman et al. 2015). A large number of alcohol-related deaths are due to accidents, for example traffic accidents, in which alcohol contributes to impaired functionality leading to fatal outcome. Data on this category of alcohol-related deaths have been reported extensively elsewhere (Wagenaar et al. 2010, Westman et al. 2015, Mäkelä et al. 2015) and are not discussed in the present report. In the Finnish medico-legal system, deaths directly caused by alcohol are categorized as either alcohol induced illness (long-term ingestion of levels of alcohol that are not acutely lethal but over time induce or contribute to fatal illnesses), or acute alcohol poisoning/toxicity (ingestion of a large amount of alcohol in a short period of time that induces a state of severe intoxication which, alone or in combination with other psychoactive substances, paralyses the respiratory centre leading to respiratory arrest and death).

It has been estimated that the total number of deaths related to alcohol in Finland in 2007, including all deaths in which alcohol was either the underlying or a contributing factor, was around 3000

deaths annually (Herttua et al. 2007). Recent years have brought about a dramatic decrease in the reported numbers of such alcohol-related deaths in Finland (Official Statistics of Finland).

In Finland, it is required by the law that all deaths in which poisoning is suspected to be a factor undergo a medico-legal investigation and thus most poisonings are closely investigated by forensic pathologists. Forensic toxicology supports the investigation by providing alcohol and drug concentrations in different matrices. As a result, there is a remarkable set of forensic data from the 32-year study period, 1987 – 2018, available for analysis.

However, especially in cases with a history of excess drinking, it is not always simple to distinguish whether acute alcohol poisoning was the direct cause of death or whether alcohol-induced illness combined with other factors to cause death. The task is further complicated by the fact that a large proportion of victims of acute alcohol poisonings also have had a history of chronic excess use of alcohol that can lead to alcohol-induced illness (Poikolainen 1977). Since there are no diagnostic anatomical or histological signs of acute alcohol poisoning, establishing the underlying cause of death is mainly based on background information and the measured concentrations of alcohol and drugs. No formal, generally accepted, criteria for determining the cause of death in alcohol-related cases have been established and thus the decision remains that of the individual forensic pathologist.

The post-mortem BAC is a key parameter that weighs heavily in the determination of whether an alcohol-related death is categorized as alcohol-induced illness or as acute alcohol poisoning. Forensic medicine textbooks often quote 3 g/kg as the lethal BAC but it can be affected by a variety of factors such as age, gender, body composition and tolerance (Johnson 1985, Heatley and Crane 1990, Koski et al. 2002, Jones and Holmgren 2003, Lahti et al. 2011, Li et al. 2017). The lethal BAC can be lower when, for example, the victim is elderly, suffered from cardiac diseases or aspiration occurred (Thomsen 2014, Saukko et al. 2016, Jones 2019). Furthermore, since the irrevocable process leading to respiratory depression starts some time before death (Jones and Holmgren 2003) and alcohol continues to be metabolised until the time of death, BAC measured post-mortem is likely to be lower than the BAC at the time death became inevitable.

Given that there is no formal, generally accepted set of criteria for categorizing alcohol-induced deaths, changes over time in the informal criteria used by forensic pathologists could occur and would impact the statistics. For example, retirement and replacement means that the population of forensic pathologists changes constantly and new science and teaching is continually being introduced. Since the post-mortem BAC level is a critical and objective parameter used in

identifying cases as acute alcohol poisonings, and we had access to this data from a remarkable time period of 32 years, we have looked for changes in BAC over time as an indicator of possible changes in the informal criteria for determining cause of death.

In most of the previous research on direct alcohol-related deaths (alcohol as the underlying cause of death), acute alcohol poisonings and alcohol-induced illness deaths have been studied as one group. In this study, however, we present the blood alcohol concentration (BAC) levels and descriptive statistics specifically in acute alcohol poisoning deaths. In this study, our specific aims were: - to examine changes over the 32-year period 1987–2018, in the numbers of acute alcohol poisonings in Finland, - to examine the demographics of such poisonings, - to determine whether changes in the median BAC in acute alcohol poisoning cases had occurred over this time period, and - to examine the proportion of alcohol-related illness deaths compared to acute alcohol poisoning deaths in post-mortem toxicology cases over the 2008–2017 time period.

2. Material and Methods

The results of post-mortem toxicological analyses along with information from the death certificate are collected into a national forensic toxicology laboratory database maintained by the National Institute for Health and Welfare (THL). Our study material came from this THL register, which contains the original cause-of-death data as provided by the forensic pathologist, as opposed to that of the national mortality statistics office, Statistics Finland, in which data have been re-coded to match international regulations (Lahti and Vuori 2002).

The analysis of BAC was performed using femoral venous blood collected at autopsy into plastic tubes containing 1% sodium fluoride as preservative. The average post-mortem interval was around 7 days and the samples were stored refrigerated until analysis. Femoral BAC was determined by two quantitative headspace gas chromatographic systems with flame ionization detection (GC-FID), always using two different analytical columns and two different internal standards. A laboratory cut-off BAC of 0.20 g/kg was applied and results exceeding 5.0 g/kg were diluted and reanalysed. The expanded measurement uncertainty (2 x U) was 2.4% for BAC of 0.4 g/kg or above and 7.6% for BAC below 0.4 g/kg. The performance of the analytical technique remained essentially unchanged throughout the study period.

Cases in the study period in which the forensic pathologist had determined the death to be an unintentional acute ethyl alcohol poisoning were included in the study. In the following sections of

this manuscript, the term “acute alcohol poisoning” is used for such cases. Note that cases in which a non-lethal level of alcohol led to a fatal accident are not considered to be acute alcohol poisonings.

In addition to the acute alcohol poisoning cases, alcohol induced-illness deaths recorded in the post-mortem toxicology laboratory database in a period of 10 years (2008–2017) were assessed. The ICD-10 codes that were used to extract cases from the toxicology database were the following: alcohol related disorders (F10), degeneration of nervous system due to alcohol (G31.2), epileptic seizures related to alcohol use (G40.51), alcoholic cardiomyopathy (I42.6), alcoholic gastritis (K29.2), alcoholic liver disease (K70), and alcohol-induced acute and chronic pancreatitis (K85.2 and K86.0).

All statistical analyses were carried out using IBM SPSS software (version 25). The analysis of changes over time was performed using the Mann-Kendall test for the existence of trends. An analysis of variance (ANOVA) was performed to test the between-group differences across basic demographic covariates (age and gender).

3. Results

In the 32-year study period between 1 January 1987 and 31 December 2018, a total of 12 126 cases fulfilled the inclusion criteria of the study, i.e. were determined to be acute alcohol poisonings. The yearly number of acute alcohol poisonings is illustrated in Fig 1.

The yearly number of acute alcohol poisonings decreased over the study period. The highest number of poisonings was seen in 2004 (N=542) and the lowest in 2017 (N=216). The decrease from 2004 to 2017 was 60.1% ($p<0.001$). The acute alcohol poisoning mortality rates for the highest and lowest year (calculated per 100 000 inhabitants over 15 years) were 12.5 and 4.7, respectively. The fall in the number of acute alcohol poisoning was more pronounced among males but also among females a minor fall, which was not statistically significant, was observed (Fig 1.).

The number of medico-legal autopsies increased from 1987 to 2009 after which a relatively rapid decrease was observed due to a governmental decision to reduce the cost associated with this activity. The changes over time in the proportion of medico-legal autopsies and forensic toxicology of all deaths in Finland are presented in Figure 2.

Of the victims of acute alcohol poisoning in this study, 80.1% (N=9711) were male. The proportion of females increased significantly over the study period from 17.1% in 1987 to 22.3% in 2018 ($p<0.001$). The proportion of females was significantly higher in the age group "45 years and older" (21.8%) than in the group "younger than 45 years" (15.1%) ($p<0.05$). This higher proportion of women in the older age group persisted throughout the study period.

The mean (median / range) age of those who died of acute alcohol poisoning was 51.2 (51.0 / 15–90) years. The mean age increased significantly over the study period as illustrated in Figure 3. ($p<0.001$). Adults aged 35–64 comprised 80.7% of the cases. Women were on average 2.5 years older than men.

The median BAC of all the studied poisoning cases was 3.2 g/kg. For males the median BAC was 3.3 g/kg and for females 3.2 g/kg. As illustrated in Figure 4. , the highest median BAC was observed in 1996 (3.5 g/kg) and the lowest in 2017 (3.0 g/kg). The yearly median BAC values showed a small but significant decrease over the study period ($p<0.001$) (Figure 4.).

Of the victims of acute alcohol poisoning, 0–3 cases per year were under 21 years old (N=37, 0.2% of all acute alcohol poisonings in the study period) with no trend over time or peak in any of the studied years. The median BAC in this age group was 3.2 g/kg.

The 3.1 to 3.5 g/kg BAC range contained the largest number of acute alcohol poisoning cases compared to other concentration ranges and this did not alter with time (Figure 5).

Excluded from our analysis are the 706 acute alcohol poisoning cases in which no BAC information was available, indicating that the alcohol concentration was measured in some alternative matrix such as muscle tissue, or that the cause of death was determined by some other means.

Between 2008 and 2017 a total of 6814 alcohol-related illness deaths were registered into the toxicology database. In the same time period there were 3586 acute alcohol poisonings deaths. The number of alcohol-related illness deaths decreased slightly over the ten-year period, being 647 in 2008 and 563 in 2017. The proportion of alcohol-induced illness deaths and acute alcohol poisonings of the total number of alcohol-related deaths in the forensic toxicology database is illustrated in Figure 6. The median BAC in alcohol-induced illness deaths was 1.0 g/kg. In 8% of the illness deaths BAC was above 2.5 g/kg.

4. Limitations

Given the absence of formal and generally accepted criteria, whether a death related to alcohol is determined to be due to acute alcohol poisoning or to alcohol-induced illness is a somewhat subjective opinion of the pathologist. Changes over time in the informal criteria used by forensic pathologists to determine cause of death could potentially produce changes in the reported incidence of acute alcohol poisonings versus alcohol-induced illness that are not an accurate reflection of the true situation. We have been able to investigate the BAC levels in these cases but do not have access to all the background information that is also used by the pathologists. However, the large sample size (cases and pathologists) will at least dilute the impact of any changes that may have occurred in the informal criteria used by individual pathologists.

In many of the acute alcohol poisoning cases in this study, alcohol was not the only substance detected. The presence of other central nervous system depressants may have contributed to the small decrease in the median BACs in acute alcohol poisoning cases seen over time since a lower concentration of alcohol is needed to suppress the respiratory system in poly-substance poisonings.

In Finland, all deaths suspected of being acute alcohol poisonings are required to have a medico-legal cause-of-death investigation, which includes forensic toxicology. Therefore this data set is essentially complete and free from selection bias. In contrast, there is no such requirement for a medico-legal cause-of-death investigation in cases suspected of being alcohol-related illness deaths and when comparing our numbers to those of Statistics Finland we noted that less than half of the alcohol related-illness deaths had been investigated medico-legally (Official Statistics of Finland). Therefore, an important limitation to this study is that with the data available, it was not possible to assess whether there had been changes over time in the criteria used to select suspected alcohol-related illness cases for medico-legal investigations. Any such changes, if they occurred, could explain the change in alcohol-related illness deaths witnessed in the toxicology database but would not explain the reduced number of acute alcohol poisonings.

5. Discussion

Death from acute alcohol poisoning is a serious and preventable public health problem all over the world but especially in Finland which has a much higher age-standardized death rate from acute alcohol poisoning than the mean of other Nordic countries (4.4 vs 1.38 deaths per 100 000 population in 2014, WHO European Health Information Gateway) (Machenbach et al. 2015).

Changes in the number of alcohol-related deaths (poisonings and alcohol-induced illness deaths) have been found to closely follow changes in alcohol consumption (Chaloupka et al. 2002, Helakorpi et al. 2010). In recent years, drinking habits in Finland have undergone major changes which are reflected in decreasing alcohol consumption numbers (Official Statistics of Finland). As a result the total number of deaths with alcohol either as the underlying or contributing cause of death has decreased markedly (Official Statistics of Finland).

Although the decreasing trend in the total number of alcohol-related deaths has been evident for some time in the statistical reports, it has not been determined to what extent changes in the numbers of acute alcohol poisonings versus alcohol-induced illness contribute to the decrease. In the present study we report that there is a highly significant decrease in the number of acute alcohol poisonings which prompted the question whether this trend is real or an artefact caused by possible changes in the process of determining the cause of death in alcohol-related fatalities. We showed that the decrease in the number of acute alcohol poisonings was not accompanied by an increase in deaths due to alcohol-induced illness in the study material, indicating that the decrease is not due to changes in the categorization of deaths between these causes. Since alcohol-induced illness deaths are normally not sudden but rather develop over time, it is likely that the numbers for alcohol-induced illness deaths tend to follow changes in alcohol consumption more slowly than those of alcohol poisonings (Nolte et al. 2003). This may explain the fact that the yearly number of alcohol-induced illness deaths in our study only showed a marginal decrease when compared to the number of acute alcohol poisonings (Figure 6). Furthermore, if the observed decrease over time in the mean BAC in acute alcohol poisonings was due to a change in the informal BAC criteria used by forensic pathologists to identify such cases, it would have resulted in an increase in the number of cases that met that criterion. Since the opposite was seen – the numbers of acute alcohol poisonings decreased over this time period – it does not seem possible that any changes in the way forensic pathologists used BAC data could be responsible for this trend.

At the time of the decreasing trend in acute alcohol poisonings there was a nearly simultaneous decrease in the total number of medico-legal autopsies. This prompts speculation that the decrease in acute alcohol poisonings could be the result of the reduced autopsy rate. However, over the same period, the rate of forensic toxicology remained nearly unchanged indicating that the reduction in the number of cases selected for medico-legal autopsies was directed at cases where forensic toxicology would not have been essential, i.e., obvious illness deaths. Therefore, it seems unlikely that the reduced number of medico-legal investigations had a significant impact on the reported number of acute alcohol poisoning. In addition, when comparing the yearly numbers of alcohol-

induced deaths in our study to those provided by the Finnish general mortality register (Official Statistics of Finland), the trends are nearly identical indicating that the proportion of alcohol-induced illness deaths that undergo a medico-legal investigation (on average 42%) has remained the same over the years in spite of the change in the number of autopsies.

Estonia has also witnessed a decrease in acute alcohol poisonings in the first decade of the 21st century but there at least a part of the decrease is likely to be a result from changes in the determination of the cause of death (Tuusov et al 2013), whereas in Finland, as we show above, the process has remained essentially the same over the 32-year study period. In Sweden, the number of acute alcohol poisonings has remained relatively stable over the last 15 years (Swedish National Board of Health and Welfare), so the decrease in Finland seems to be an independent phenomenon and not something the neighbouring countries shared.

The median BAC in the 32-year study period was 3.2 g/kg and the yearly median BAC showed a slight decrease over the study period. The median BAC in our study was the same as the median of a series (N= 656) of accidental mono-intoxication deaths caused by alcohol in Sweden (Jones et al. 2011) and close to the mean of 39 acute alcohol poisoning deaths in Turkey (322.8 ± 155.5 mg/dL) (Celik et al. 2013). Some other studies found higher medians of 3.6 g/kg (Jones and Holmgren 2003) and 3.55mg/100 mL (Heatley and Crane 1990) but in these studies the cases involving other psychoactive substances were removed whereas in our study they are included. Higher levels of alcohol are to be expected in cases of fatal mono-intoxication due to alcohol versus cases in which other psychoactive substances were also present. The biggest group in our material was those who had a BAC between 3.1 and 3.5 g/kg; in most years of the study period more than ¼ of the cases fell into this category.

The slight decrease in the median BAC in acute alcohol poisoning cases seen in the study period might be related to the increasing age of the victims since older age is associated with stronger effects of alcohol on the human body. In addition, there is more therapeutic polypharmacy in the elderly and the recreational abuse of psychoactive drugs in combination with alcohol has in general become more prevalent in recent years (Hakkarainen and Metso 2009). These phenomena may have contributed to the decrease in the median BAC since less alcohol is needed to cause death in the presence of other central nervous system depressants. In the current study we did not assess the concomitant use of other psychoactive drugs before death.

The vast majority (80.7%) of the victims of acute alcohol poisoning in our study were aged 35–64 which is a similar finding to that of a study of acute alcohol poisonings in the United States, where

the percentage was 75.7% (Kanny et al. 2015). Thus, acute alcohol poisoning remains for the most part a problem of the working-age population. We found that, the mean age of the victims of acute alcohol poisoning increased steadily over the study period from 47 years to over 55 years. Women were on average 2.5 years older than men. The overall proportion of women in the study period was 19.9% but a significant increase in the proportion was seen over the 32 years of the study from around 16% to nearly 25%. The latter is close to the proportion seen in Sweden where 24% of the victims of acute alcohol poisonings were women (Jones and Holmgren 2003). It has been shown in previous research that women are in general less likely to start drinking excessively and therefore less likely to develop alcohol-related medical problems than men (Erol and Karpyak 2015). However, those women who do drink excessively develop more medical problems than men (Erol and Karpyak 2015), which may be associated with the proportionally lower BAC in females found in this study.

The increasing mean age of the victims of acute alcohol poisoning over time reflects the fact that the decrease in the total number of such cases is concentrated in younger age groups. Whereas the number of acute alcohol poisonings has decreased steeply among males, the number for females has been stable resulting in an increase over time in the proportion of women among the victims of acute alcohol poisoning. This is consistent with previous research that has shown that gender differences in the alcohol use patterns and the related outcomes have become narrower in recent years (White et al. 2015).

There is evidence that acute alcohol poisonings are widely underreported, particularly in countries in which the rate of medico-legal toxicology investigations is low (Lahti and Vuori 2002, Yoon et al. 2003, Rahu et al. 2011, Lahti et al. 2011). Given the high rate of such investigations in Finland there can be more confidence in the numbers and trends reported in our study.

Heavy alcohol consumption is associated with high morbidity and mortality (Rehm et al. 2010, Norström and Ramstedt 2005). When an autopsy is performed in a case of alcohol-related death, the forensic pathologist is responsible for categorising them as either alcohol-induced illness deaths or acute alcohol poisonings, based on the individual pathologist's interpretation of the toxicology reports and background information. The total number of medico-legal investigations in Finland is very high (more than 8500 medico-legal autopsies in 2017) but the number of practicing forensic pathologists is rather limited: over the 32-year study period the total number of individual forensic pathologists contributing to the studied material was around 70, with 25–30 pathologists active in

any given year. The resulting high caseload for each pathologist may assist in the cause-of-death data being relatively consistent.

As discussed above, in many countries the statistics of alcohol mortality underestimate the acute alcohol poisoning component due to the low rate of medico-legal autopsies. However, it is important that policymakers know the true incidence and nature of alcohol-related deaths for an appropriate allocation of prevention measures. This report on the incidence, demographics and trends over time of acute alcohol poisonings in Finland is likely an accurate representation of the true situation that can be relied upon by policymakers.

6. Conclusion

In this study we presented the descriptive statistics for acute alcohol poisoning in Finland for a period of 32 years based on an exceptionally high number of cases, establishing the real-life BAC distribution in these cases. We showed that the significant decrease in the number of acute alcohol poisonings in recent years is not likely to be a result of changes in the medico-legal practice of determining fatal poisoning but a real phenomenon that reflects changes in the overall consumption of alcohol.

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Contributors

Ilkka Ojanperä conceived of the presented idea and encouraged Pirkko Kriikku to investigate the alcohol poisoning deaths in Finland. Pirkko Kriikku performed the database searches and statistical calculations, and wrote the manuscript with input from Ilkka Ojanperä. Both authors have read and approved the final manuscript.

Conflict of Interest

No conflict declared

Conflict of Interest

None

Author contribution statement

Ilkka Ojanperä conceived of the presented idea and encouraged Pirkko Kriikku to investigate the alcohol poisoning deaths in Finland. Pirkko Kriikku performed the database searches and statistical calculations, and wrote the manuscript with input from Ilkka Ojanperä.

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Figure 1. Yearly numbers of acute alcohol poisonings for males and females, and for the two age groups, in 1987–2018.

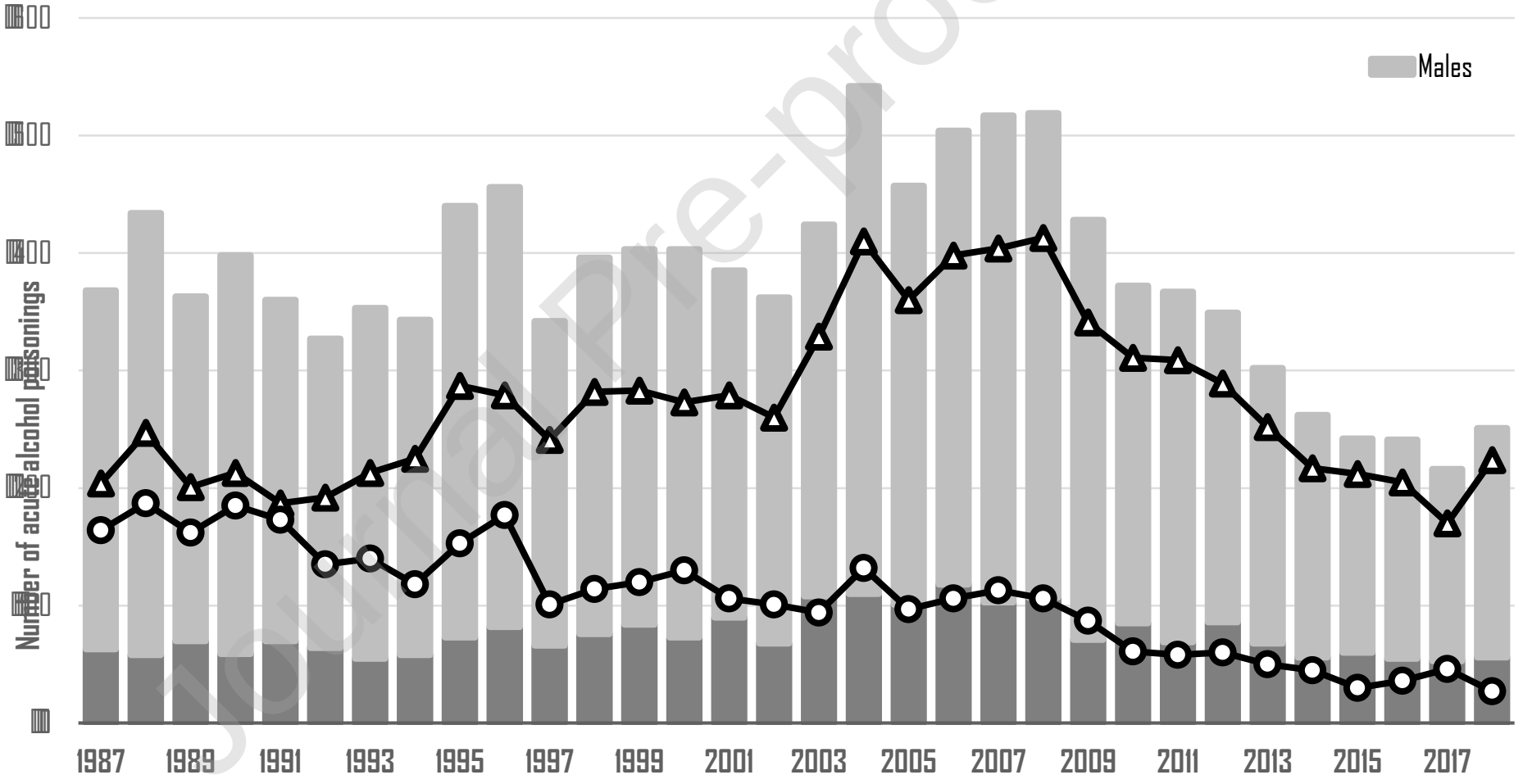

Figure 2. Acute alcohol poisoning mortality rate (per 100 000 inhabitants) in the general population aged 15 years and above between 1987 and 2017, and the proportion of medico-legal autopsies and forensic toxicology of all deaths. Numbers for all deaths and inhabitants over 15 years were obtained from Statistics Finland.

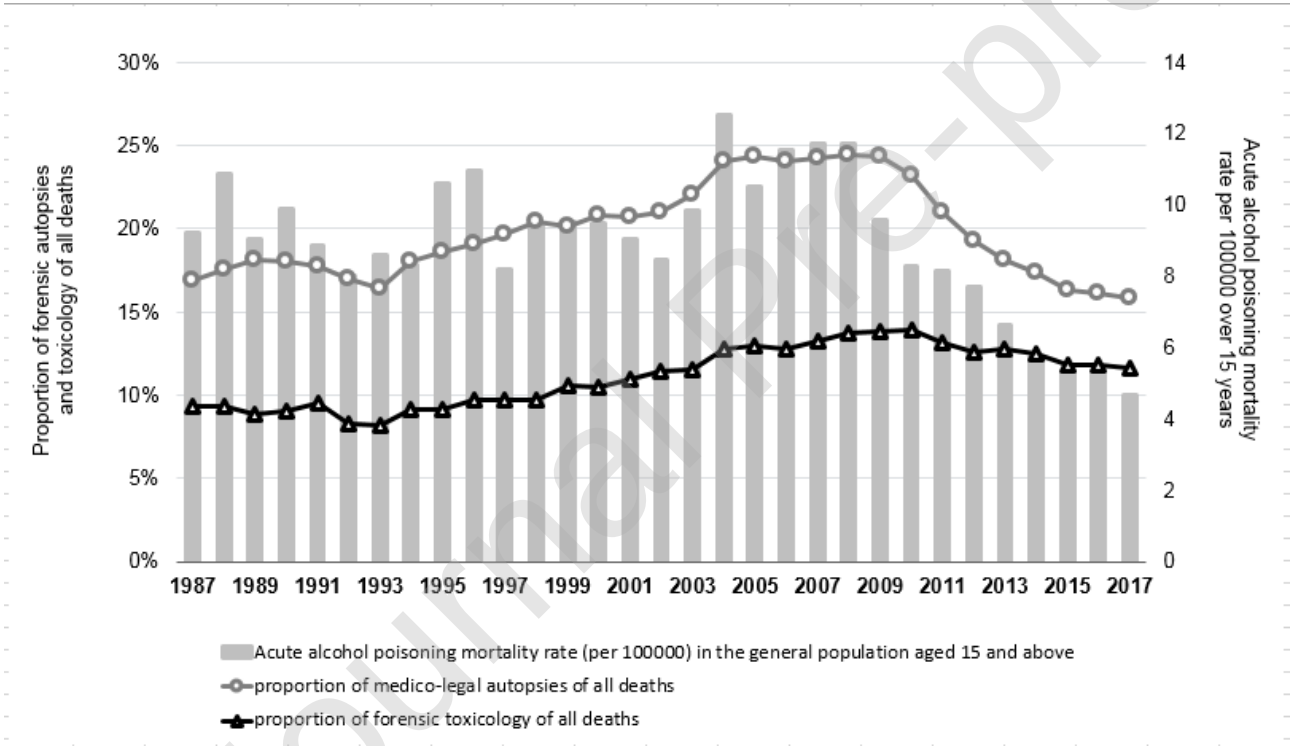

Figure 3. Mean age at death in acute alcohol poisonings in 1987–2018.

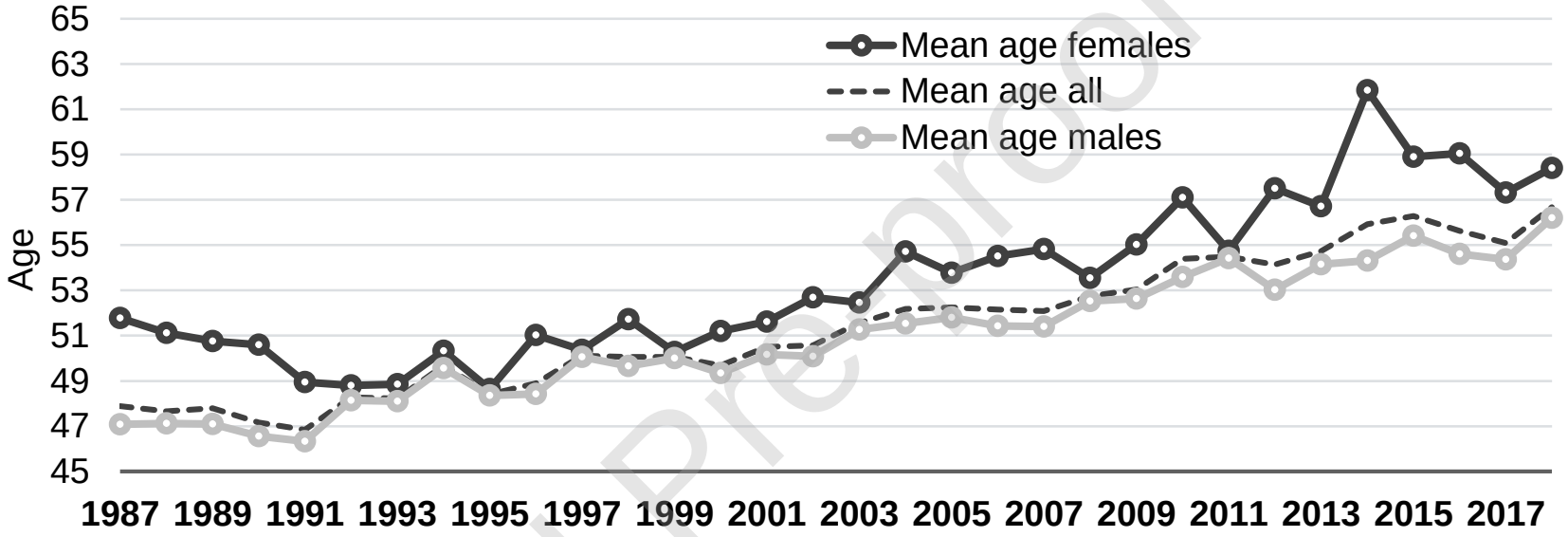

Figure 4. Yearly median BAC in cases of acute alcohol poisoning from 1987 to 2018.

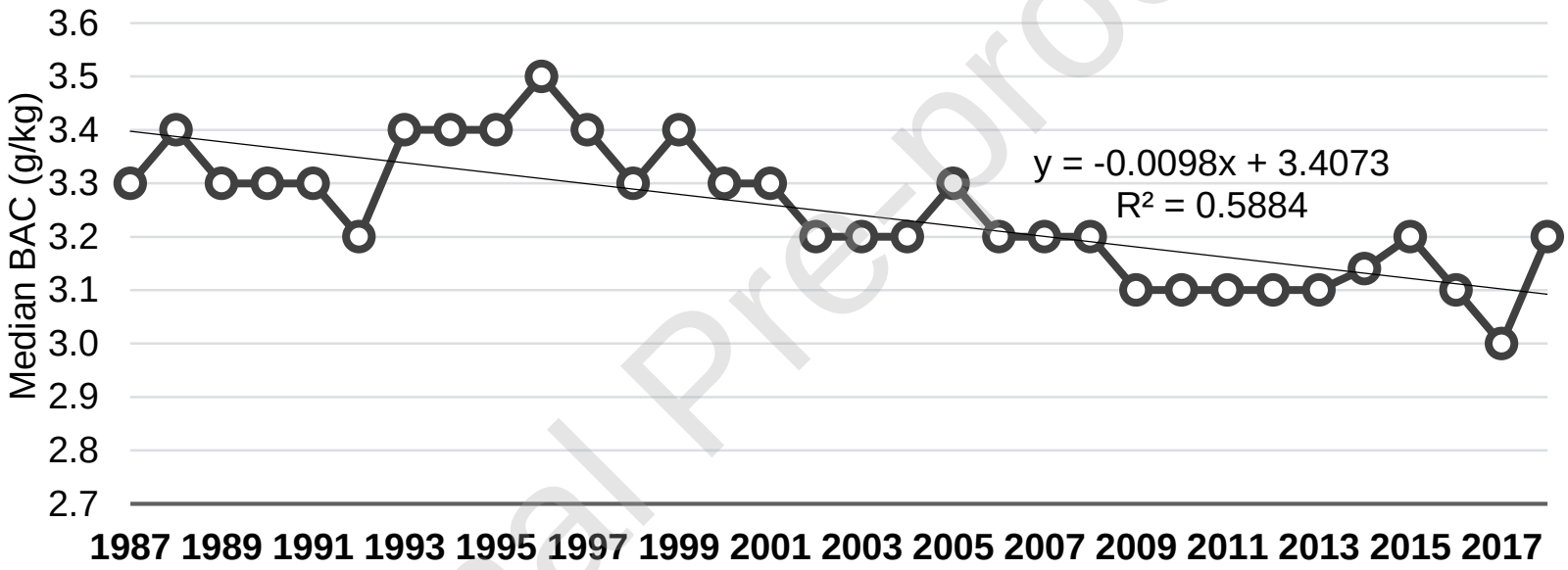

Figure 5. Frequency distribution of the median BACs in acute alcohol poisonings in 1996, 2017 and in the whole study period in 1987–2017.

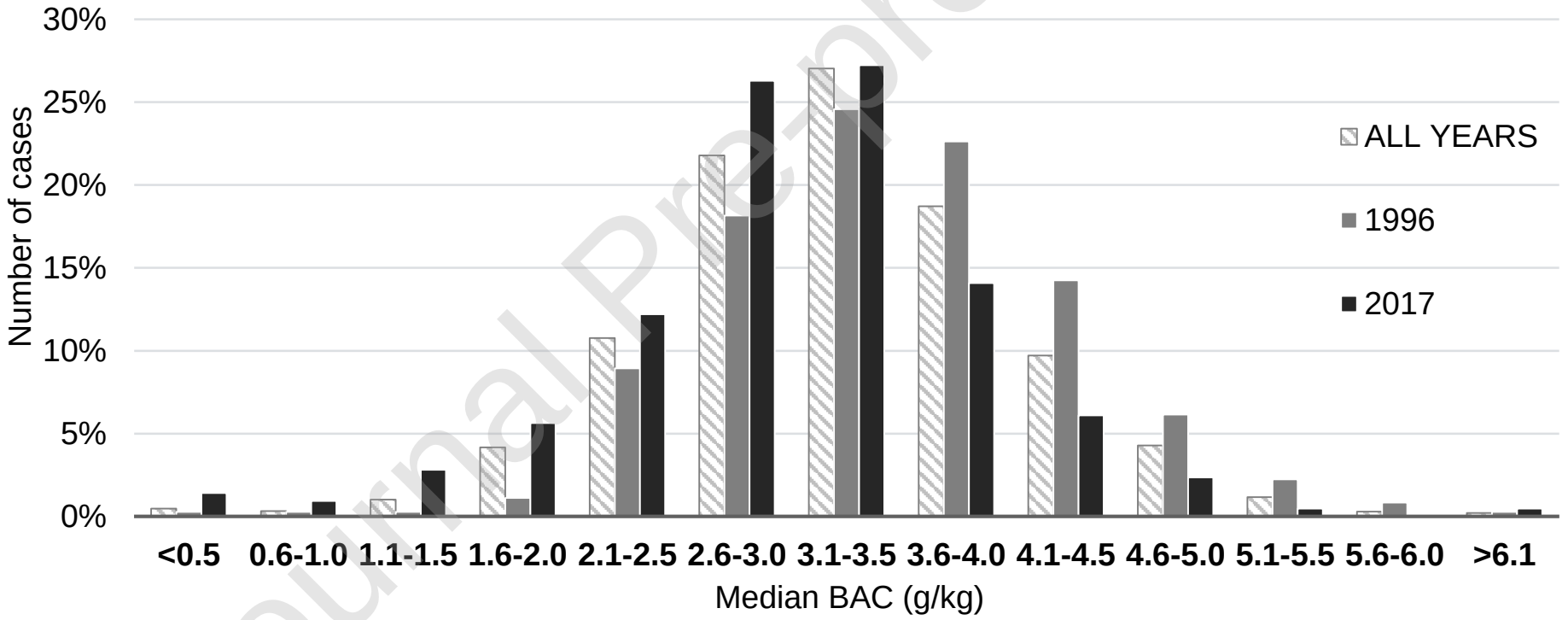

Figure 6. The incidences and proportions of alcohol-related illness deaths and acute alcohol poisonings recorded in the toxicology database from medico-legal investigations in 2008–2017.